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Interactive Accessibility for the Visually Impaired

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Light Exhibit Extensions for the Visually Impaired

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Submitted to:
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Abstract

To help those visitors with visual impairments access the experiences and content presented in the light area in Launch Pad (a hands-on gallery at the Science Museum London), two exhibit extensions were developed. Exhibit extensions are tools that allow visitors to interact with the phenomena of an exhibit on a personal level. These exhibit extensions dealt with the reflective abilities of light and the color spectrum of natural light, and allow visually impaired visitors to conceptualize the scientific principles involved through tactile and auditory means. Throughout the Museum, such extensions allow the visitor to interact with a scientific display on a personal level, and in this case, the extensions bridge the gap in the understanding between those who experience visual phenomena and those who do not have sight or whose sight is limited. The design of the exhibits was supported by research into techniques for educating the visually impaired.

Acknowledgments

The success of this project is not solely placed upon the authors of this report; there are many others who have made our work possible. We first would like to thank our on-site liaisons, Alex Burch and Rachel Church. Both have brought “brilliant” ideas and suggestions and have always shown openness to our own thoughts. We also must acknowledge Ken Chan, Steve Long, and the workshop crew who have helped in every request we have had. Everyone involved in Visitor Research, as well as the Explainers have helped us to fully understand this museum and its goals. We must not forget Caroline Mark for keeping it real in the office and the lovely Charlotte Hyde for donating her time and voice. Finally, we would like to express our sincere gratitude to our project advisors. Dr. Addison and Prof. Delorey have helped in innumerable ways. The past fourteen weeks success would not have been possible without their criticism and support.

Executive Summary

The Science Museum, London is currently developing a new interactive gallery called Launch Pad. This gallery will consist of fifty hands-on exhibits spread over six content areas: light, materials, energy transfer, forces and motion, electricity and magnetism, and sound. As part of the development, the Museum is eager to ensure that the exhibits and experiences are accessible to as broad a range of users as possible. The objective of this project was to identify ways of increasing access to the light exhibits in the Launch Pad Gallery to those users who are visually impaired. Visual impairments impede the learning experience revolving around light because sensorial data gathered by light is either absent or limited in some way. However, sight is just one of the senses and there are many other media through which a child who is visually impaired can learn about and experience the nature of light. The Disability Discrimination Act (DDA), an act passed in the United Kingdom, requires that all establishments make material accessible to those with disabilities.

Our goal was to create extensions to several exhibits in the light area that will allow visually impaired children to interactively learn about light. Extensions are assistive learning units specifically catered to the disabled that are kept within the Launch Pad and are brought out by the Explainer staff. Our approach was to consider ways of making the exhibit enjoyable and accessible beyond just the use of audio or Braille explanations, which can be bland. Instead, we chose to adopt tactile and audio senses into our proposed extensions in order to make these exhibits educational and enjoyable without just verbally explaining the concepts.

Museums, such as the Science Museum, London, and schools, such as Perkins School for the Blind in Watertown, Massachusetts, try to teach about light and its properties to the visually impaired but have found difficulties in effectively doing so. Difficulties have arisen because

until recently technologies have lacked the ability to cater to the visually impaired as well as that until the passing of the DDA most of the disabled community has been ignored by society. Learning institutions need a method to teach difficult scientific concepts in a more enriching, fulfilling manner that provides a more complete understanding of the subject.

We believe that our prototype exhibits will be successful in portraying some of the properties of light that are being displayed in the Launch Pad exhibits to the visually impaired in an interactive manner. Through surveys, interviews, a focus group, and naturalistic observations we obtained the information necessary to develop the prototypes of the extensions. We hope these will eventually provide an example to other educational institutions as to ways to include the visually impaired in their interactive exhibits, especially pertaining to light. To accomplish our goal we completed several objectives:

1. Determine the characteristics of the proposed Launch Pad light exhibits
2. Identify and evaluate current and previous museum adaptations for the visually impaired
3. Assess children with visual impairments' perception of light
4. Design and create the prototype extensions

Our first order of business was to get a full understanding of the Launch Pad gallery by reviewing plans for its creation. This gave us information on which topics the exhibits were portraying so we could capture this in the extensions. We also examined the current exhibits adaptations for the visually impaired at museums in London. This was done by assessing other exhibits through interviews of the Science Museum, London designers and staff. Current museums and extensions also provided us with information on what had been done before and what needed to be improved. Focus groups conducted with visually impaired children as well as separate meetings with educators provided us with personal input on what they can understand and relate to with respect to light. With all this information, prototype extensions were developed that satisfied the educational needs for the exhibit in a more interactive way than what has been used in the past.

Interactive extensions designed for the visually impaired can facilitate the adaptation of experiences beyond the museum. Adequately displaying an exhibit that relies almost entirely on sight into an alternate medium could influence how other museums as well as schools approach educating the visually impaired. The work that we did at the Science Museum, London is not to just accommodate someone with a disability, it was to give the visually impaired the educational experience that they deserve. In addition, we hope that the extensions will provide an additional layer of interpretation to other visitors without visual impairments.

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1. Introduction

Imagine a police siren if you could not hear. Imagine apple pie if you could not taste. Imagine perfume if you could not smell. Imagine light if you could not see. Forty-four million people on this planet are completely blind, which is nearly one-percent of the world's population, with many more visually impaired. Because the visually impaired cannot fully experience the sighted world, new methods of communication have to be developed to help them understand this world. In the past tactile systems, such as Braille, have been used, as well as audio technologies; however, tactile models have been the major learning tools used by the visually impaired in recent years.

The Science Museum, London, is embarking on an initiative to ensure that their exhibits are as accessible to as broad an audience as possible. This includes trying to find ways that those with visual impairments are able to interact with and learn from exhibits about light. The London Science Museum has developed many exhibits over the years, but most exhibits utilize the senses of touch and sight to relate information. Because museum exhibits primarily make use of visual and tactile senses, the visually impaired are not always able to fully access the content presented. The Science Museum is currently redeveloping its Launch Pad gallery, as part of this there will be an area containing seven exhibits exploring different aspects of Light. This means that there is a need to find effective ways of relaying concepts about the characteristics of light to those who are visually impaired. This is particularly challenging given that sight is the primary way that light is experienced.

Other institutions, such as the Boston Museum of Science (Boston, MA) and the Perkins School for the Blind (Watertown, MA), communicate to the visually impaired through tactile and auditory means. The visually impaired must use their senses of touch and hearing to understand visual concepts of the physical world. At the Perkins School for the Blind, as an example, they have compiled a book of raised pictures to relate scientific concepts and information for their visually impaired students.

The concepts of light have been largely overlooked in mainstream education as material to be explained to the visually impaired because of the challenge posed by creating ways to teach the visual impaired about light. Currently, the Science Museum, London exhibits focuses primarily on auditory narrative explanations of the phenomena involved in an exhibit to explain the information both to the general public as well as the visually impaired. This can often leave the visually impaired with an incomplete understanding of the concepts being presented.

How to make exhibits about the nature of light accessible to those who are visually impaired, particularly those who are blind, is a particularly challenging question since we experience light through sight – the very sense that is affected for those with visual impairments. The goal of the Launch Pad Gallery is to "inspire you to explore and question science and technology through hands on experience of real phenomena in an environment that promotes curiosity" (Burch, 2007). Our project's goal was to develop prototypes through which the visually impaired can use other senses to understand the phenomena of light. To develop these requires the use of techniques and adaptive technologies currently employed to teach the blind and visually impaired. The Science Museum, London will use similar techniques to those in the classroom.

Furthering the development of more exhibits designed for the visually impaired will help them to access other visual phenomena not typically understood or taught to them. By supplementing the education of the visually impaired, they will have a better understanding and concept of the world in which they live.

2. Background

This chapter examines methods on educating the visually impaired about the properties of light through alternative methods. The three main research areas are: teaching techniques for the visually impaired, properties of light, and visual impairments. The knowledge from each of these areas must be brought to bear on the design of an effective prototype that will explain the properties of light to the visually impaired.

2.1 Forms of Visual Impairments

Every human being has the same eye structure (Newell, 2001). Damage, deformity, or degeneration to any part of the eye can cause visual impairment. Understanding the various types of visual impairments requires basic knowledge of the structure of the eye (Appendix C). So that museum exhibits can be properly adapted to the visually impaired, the various types of visually impairments must be studied. There are many forms of visual impairment, each with a unique alteration of the eye structure or the normal functions of the eye. There are two forms of visual impairments, complete blindness or partially sighted.

2.1.1 Complete Blindness

The World Health Organization (2004) estimates that between 0.2% and 0.5% of any industrial nation's population is legally blind. There are two general categories of blindness. Some people can perceive light to some degree but not objects, and others cannot perceive light at all (Matsuoka, Luxton, & Rogers, 2001). For a complete explanation of all the various diseases that cause blindness and other eye conditions, see Appendix D.

Through various diseases or external events, anyone can lose the ability to see completely. Birth defects, genetics, and poisons can all cause blindness. A person can lose the ability to distinguish objects with partial blindness – this means that they see light, but no objects or images are distinct. Complete blindness involves the loss of all ability for the eye to process light (Matsuoka, Luxton, & Rogers 2001). One common cause of complete blindness is Cortical Visual Impairments, these are linked to an underdevelopment of or damage to the nerve-eye-brain connection (New Hampshire Agenda for the Education of Student with Visual Impairments Goal One Committee, 2001).

2.1.2 Visually Impairments

According to a recent report by the New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee (NHGOC) (2001), there are three types of visual impairment categories: refractive errors, eye conditions, and Cortical Visual Impairments. While the first two are structural damages to the eye, the third is caused by nerve damage, causing a loss of information to or from the eye to the brain. Cortical Visual Impairments are referred to above. Refractive errors are easily corrected by glasses, and therefore will not be discussed here. A description of refractive errors can be found in Appendix D.

Color Blindness

Color Blindness is a unique visual impairment that has little to no affect upon the effected person; however, so that the color blind can understand the concepts presented to them, research on color blindness is needed. Colorblind people often cannot recognize a difference in color when two specific colors are placed next to one another.

According to Dr. Richard S. Kockman (2001) of St. Luke’s Hospital in New York City, Color Blindness affects about six percent of the male population and has the most imprecise definitions of all visual impairments. Colorblindness is a male sex chromosome related condition. While people can develop colorblindness through deterioration of the retina or the development of cataracts, it is typically a genetically linked occurrence. There are three types of color blindness: Red and Green Defects, Yellow and Blue Blindness, and Monochromatic Blindness. Red and Green defects dull the red and green spectrum so that the colors are not as intense as they would be for someone with normal vision. Yellow and Blue blindness, a rare form of color blindness, occurs when the retina becomes diseased. The person cannot see yellow or blue; objects appear in shades of Red, green, black, and white. Monochromatic Blindness, the rarest form of color blindness, removes all colors of the spectrum from a person's sight. The male can only see in the gray scale spectrum.

Tunnel Vision

NHGOC (2001) also focused on tunnel vision, scientifically called Retinitis Pigmentosa, because it involves the slow degeneration of the cones and rods within the retina. Along with losing central vision, a person also develops forms of color blindness as well as night blindness. Night blindness is the loss of ability to see well in dimly lit areas or at night. Because of this partial blindness, those with tunnel vision require special considerations in the design of our extension.

2.2 Properties of Light

Light is defined as a form of electromagnetic radiation that can be detected by the eye. Light travels in the form of a wave at 186,282.397 miles per second. It reflects off objects into the eye where it is focused onto the retina and then processed by the brain to form an image. The project focuses on the light sections of the Launch Pad exhibits. Each of these sections portrays different properties of light through an interactive exhibit.

2.2.1 Incandescence

Incandescence is the process by which thermal radiation is released from an object usually in the form of light and heat (Hopkinson, 2001). The hotter an object is the more light it produces. This form of light has four main colors: red, orange, yellow or white. Some examples of incandescence are fire, incandescent light bulbs, and the sun.

2.2.2 Luminescence

Luminescent light is produced without heat (Hopkinson, 2001). It is created by the movement of electrons within a substance from more energetic states to less energetic states. Some examples of luminescence are: things that glow in the dark, television screens, fireflies, fireworks, and energy-saving light bulbs.

2.2.3 Visible Spectrum

White light is the combination of all colors of the visible spectrum, which is the combination of all wavelengths of visible light (Di, 1973). The visible spectrum is called ROYGBIV, this stands for Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Each of these colors is unique to a varying frequency of the light wave.

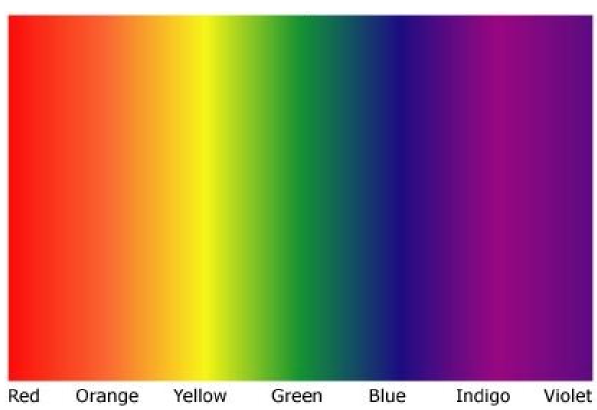

Figure 1: Visible Spectrum
(Global Science and Technology, 2007)

2.2.4 Reflection

Reflection is the property of light that occurs when a light wave bounces off an object changing the direction of the wave (Hopkinson, 2001). *Specular reflection* is when the light waves stay intact so that the image of the item being reflected appears on the object that is reflecting the light. *Diffuse reflection* is when the energy of the light is reflected but the light is spread out so the image does not appear distinct.

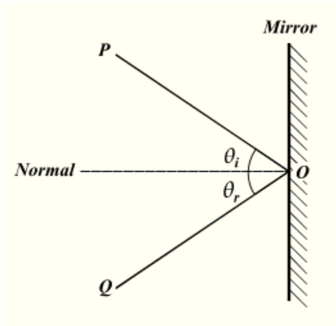

Figure 2: Reflection
(Web Physics, 2007)

2.2.5 Refraction

Refraction occurs when the speed of a light wave changes causing the light wave to change direction (Hopkinson, 2001). The speed of the wave is changed by traveling through two different media. For example, when light travels from air to glass to air, the image does not appear to be in the same place as the object actually is.

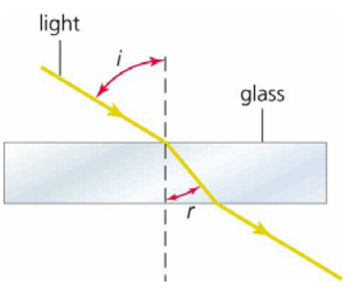

Figure 3: Refraction
(Academy Artworks, 2007)

2.2.6 Lenses

A lens is a device that manipulates light, using the principles of refraction, in order to focus it or diverge it (Smith, 2001). A lens is usually a piece of glass or plastic that is shaped in a particular manner. Lenses come in two main shapes. Convex lenses focus a broad range of light into a single point, because of its characteristics this lens is used to shrink light into a smaller image. Concave lenses take a broad range of light and diverge it to increase the size of an image.

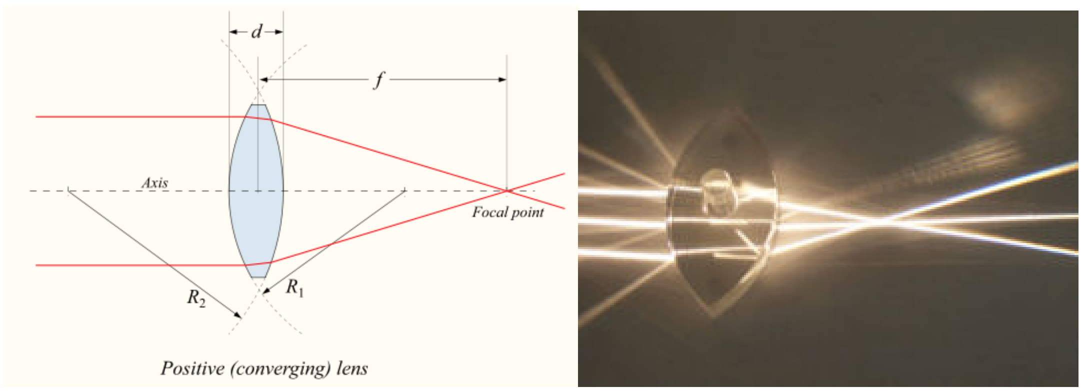

Figure 4: Convex Lens
(Wikipedia, 2007b)

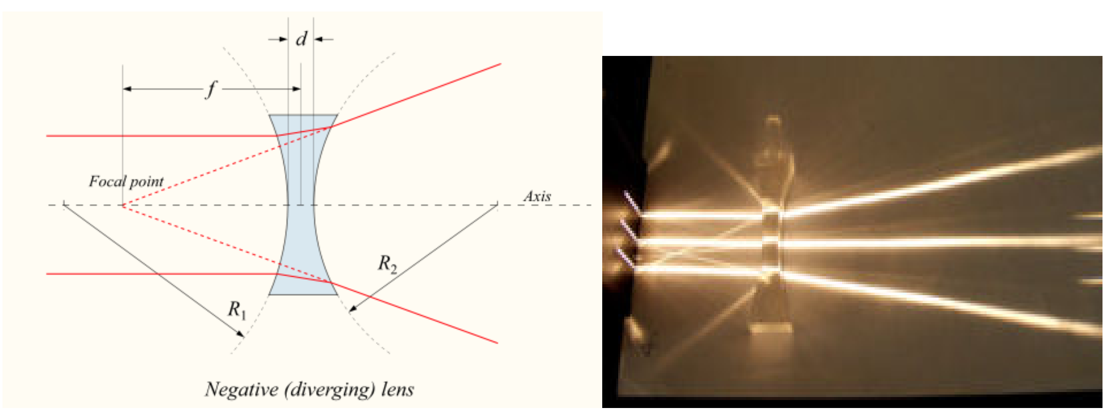

Figure 5: Concave Lens
(Wikipedia, 2007b)

2.3 Teaching Methods

The way one interprets the world is based on one's senses. Vision is the main sense that sighted people rely on to learn. Sighted people relate and recognize objects by what the object looks like or appears to be, rather than by use of the four other senses (Tactile Book Advancement Group, 2006). The majority of the visually impaired have no knowledge of what an object "looks like." How *should* an object be described? Visually impaired people rely heavily on touch to perceive the world; therefore, for them things should be described in a tactile manner (Tactile Book Advancement Group, 2006). The standard science text book, however, relies heavily on word and diagrams. When teaching the visually impaired, the teachers at the Perkins School for the Blind use textbooks with raised images and different textures to relay these images to the students. The company through which all of their tactile textbooks are purchased is American Printing House, of which the science textbook is *Basic Science Tactile Graphs*. They also use models of the subjects being taught in the textbooks, such as animals or buildings, that the students can touch and feel to form an idea of what is being taught.

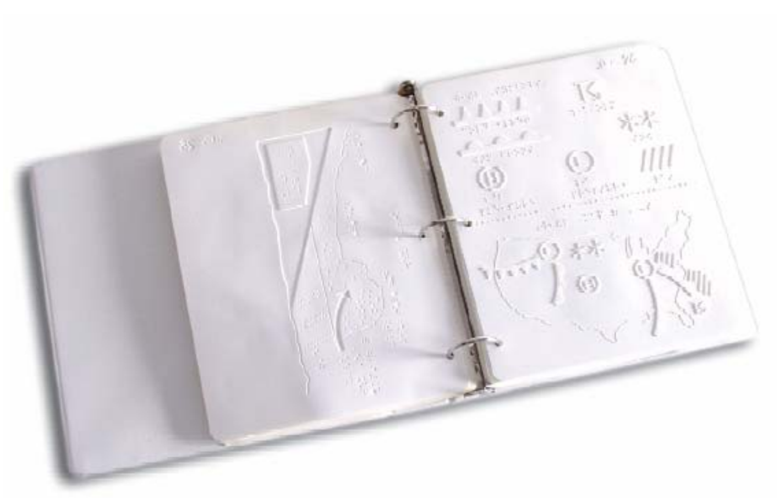

Figure 6: *Basic Science Tactile Graphs* used at Perkins School for the Blind

2.4 Museum Exhibits

Many large museums have extensive exhibits where guests are only allowed to look and must not touch the displays. This poses a problem for people who have visual impairments of course because they cannot experience the exhibits. The Metropolitan Museum of Art in New York City has developed some unique ways to allow the visually impaired to experience and learn from the exhibits. They have created a special set of exhibits and exhibit extensions designed for people with visual impairments. The Metropolitan Museum of Art has developed special touch exhibits where the visually impaired are allowed to touch everything in the exhibit. In their Ancient Egypt exhibit people with visual impairments are allowed to touch all of the statues to get a sense of what they are. The museum also offers verbal imaging tours describing the exhibits in great detail. Other museums have what are called "Explainers" at some exhibits where if asked they can explain the exhibit to you in great detail (Metropolitan Museum of Art, 2007).

2.5 Exhibit Extensions

With the passing of the Disability Discrimination Act in 1995, it became the legal necessity of the museum to be accessible for all visitors (DirectGov, 2007). There are many ways in which this can be done, including audio guides, good exhibit design, and exhibit extensions. One of the approaches adopted by the Science Museum, London staff on the Launch Pad redevelopment project is to develop extensions to exhibits. Extensions are assistive learning units catered to the disabled that will be kept within the Launch Pad and are available upon request.

Given that all exhibits within Launch Pad will be interactive, the exhibit extensions (for those with disabilities) should not be passive. There are two key aspects to an exhibit, the subject matter and the overall experience. The subject matter is the scientific data that the exhibit wants to communicate to the visitor, and the experience is the interaction of the user and the act of having fun while using the exhibit. Given that the extensions we are developing have the specific aim to facilitate access to the concepts of light which are not possible through the exhibit itself (for those with visual impairments) then the goals for the extension must be the same as the exhibit; to have interactivity of the user and to communicate the scientific data focused on.

2.6 Assistive Technologies

Humans depend on visual sense for 80% of external information (Takao, Sakai, Osugi, Hiroaki, 2002). Without sensorial access to clear visual information, children who are visually impaired are at an educational disadvantage unless assistive technologies are used. Assistive technologies are the tools that facilitate communication of information to the disabled (Galvin & Scherer, 1996). Assistive technologies that appeal to the sense of touch, sound, taste, and smell can be used to communicate with the visually impaired.

2.6.1 Visual

For people with limited vision, there are some visual techniques that can be adopted to help them access the information more effectively. For example, it is recommended that to make things as clear as possible, keep graphical information as simple as possible and avoid unnecessary overlapping of objects, as well as use distinct, contrasting colors and strong outlines (Tactile Book Advancement Group, 2006). For example if someone is colorblind, then troublesome color combinations such as green and red must be avoided so that the person can clearly identify what they see (Matter, Hoffman, Dion, & Becker, 2000).

2.6.2 Tactile

The sense of touch is a powerful and effective sense but perhaps one that is often underutilized. Through the sense of touch, deaf-blind people can learn and lead fulfilling productive lives (Davidson, 1989). The best-known form of tactile communication is Braille. Braille is widely used by blind people to read and write in the United States. A Braille character has six dot positions, arranged in two columns of three dots each. A dot can be raised at any of the six positions, giving sixty-four potential letters (American Foundation for the Blind, 2007). There are two types of Braille: grade one and grade two (Cabrera, April 25, 2007). Grade one words are spelt out letter by letter. Grade two uses a shorthand technique for common words such as “and”, “for” and “the.” Grade two is preferred, but for short labels on a museum exhibit grade one is acceptable. The use of Braille is declining as the use of computers with synthetic speech is becoming an accessible form of assistive technology (Faherty, 2006).

While Braille is on the decline, one form of tactile communications is becoming more widely used. According to an article in the British Journal of Visual Impairment,

> Tactile maps and diagrams have been available in some form for centuries, and now have increasing significance in the lives of blind and visually impaired people for education, work and leisure, as graphical information becomes ever more prevalent and central in our daily experience.

While some information that can be understood linearly with Braille; tactile devices that can be experienced in all three-dimensions are useful for three-dimensional data. Tactile maps and diagrams need to be carefully designed in order to be readable by the visually impaired user (Johoel, McCallum, Rowell, & Ungar, 2006).

A group of researchers conducted a study to determine the best material and minimum separation between two lines for tactile graphics (McCallum, Rowell, & Ungar, 2006). They determined the best material for tactile diagrams is rough paper but if something more durable is required rough plastic is suitable. Two lines must be at least 1.3 mm apart to be distinguished as a double line.

The Tactile Book Advancement Group, located in the United Kingdom, has a list of proper techniques to use when constructing tactile books (Tactile Book Advancement Group, 2006). They recommend using different and distinct materials to create varying textures for elements in the picture including: plywood, foam, felt, sandpaper, buttons, beads and sponges. They also recommend the use of simple shapes that don't overlap and to avoid images with perception; try to keep the viewpoint two-dimensional. Using various materials for textures gives more tactile information but is harder to quickly reproduce (Grice, April 25, 2007).

Tactile representations are used for more than just diagrams and maps, they can also be used to represent everyday objects (Tactile Book Advancement Group, 2006). This is something that is seen more in children's books as illustrations and in children's toys and games. The representation of the object must be meaningful to someone with visual impairments. For example, a leaf would be a better representation of a tree than the tree's outline because a visually impaired person, especially a child, can relate to the feel of a leaf better than the shape of a tree.

2.6.3 Auditory

In the most basic sense, a painting or object can be described verbally. Using auditory explanations or exhibit explainers or other methods to describe verbally an exhibit is one of the major ways to relay information to the visually impaired and is used at museums world wide. However, an auditory explanation about something like light poses a problem. It is something that is more easily explainable with visual means.

The problem lies in the fact that most humans depend on visual cues for most external information (Takao et al., 2002, p.66). The nature of light also poses a problem as you cannot hear light, you cannot touch light, and you cannot smell light. However, the auditory sense has become much more important in relaying information with constant advancements made in audio technology (Faherty, 2006). Such technologies can be used "to reduce the load on the visual sense… with an AUI (Audio User Interface), information can be removed from the visual channel and presented through the auditory channel" (Alty, 2005, p.24). This process occurs in the brain and can produce aural images and can "communicate more effectively multimedia information" (Alty, 2005, p.24). It is this aural image that could be extremely useful in portraying light to children in the Launch Pad exhibit.

A great deal of the new computer interaction with the visually impaired is due to the growth in speech recognition technology which allows humans to relay information to machines as one would to another human. These improvements give the visually impaired an opportunity to operate computers and complete daily tasks.

2.6.4 Heat, Smell and Taste

Heat, smell, and taste are not commonly used as assistive technologies. An extensive search revealed no relevant printed resources that discussed using heat as a tactile device, or smell and taste as an assistive technology. Because heat acts similarly to light, it bears further investigation as a possible avenue for the extensions. An analogy can be made between the intensity of heat and the intensity of light can be related. At this time, a connection between taste or smell and light is unknown, but these also bear further investigation so that as many senses as possible can be encompassed in the extensions.

2.6.5 Review of Assistive Technologies and Teaching Light

These assistive technologies are the foundation for the development of prototypes at the Science Museum, London. Visual aids must be simple and basic to avoid confusion by any user. Braille and tactile diagrams can be used to provide an explanation and give additional information as to what the exhibit is portraying. Audio technologies can provide clear directions and descriptions to the user but advancements are making computer interaction more prominent. Other senses such as heat, smell, and taste can also aid in the experience with an exhibit.

Combining these assistive technologies can be extremely helpful for the visually impaired in conceptualizing objects and phenomena. Despite such technology allowing the visually impaired to better interact and experience more at the museum, there is little information on conveying to the visually impaired the scientific concepts of light and it poses a significant challenge (Takao, Sakai, Osugi, Hiroaki, 2002). The challenge is not only finding a practical solution to the lack of interactive experience for the visually impaired at the museum but to socially accommodate them as well in the pleasures involved in visiting a museum..

3. Methodology

The goal of this project was to develop extensions for several exhibits in the light section of the Launch Pad gallery of the Science Museum, London so that people who are visually impaired will be able to interact with the exhibit and understand the concepts presented. To accomplish this, we identified four objectives necessary to achieve our goal. These four objectives are: determine the characteristics of the proposed Launch Pad light exhibits, identify and evaluate museum adaptations for the visually impaired at other museums in London, determine visually impaired children's perceptions of light, and finally, propose and design the extensions for the visually impaired. To accomplish our objectives, we conducted interviews and focus groups. This chapter will address each of our research points and explain in detail the methods we chose to pursue them.

To achieve most of our objectives we met with teachers of the visually impaired and their students. One factor that constrained our project was setting up and conducting the meetings within six weeks of our arrival. To facilitate scheduling we made contacts within the museum and with area schools for the visually impaired as soon as we arrived in London. Our liaisons, Alex Burch, Senior Visitor Researcher, and Rachel Church, Visitor Research of the Launch Pad Project, helped us make the initial contacts.

Because of the difficulty with data collection, we sought out new contacts at the museum and with those who specialize in educating the visually impaired for specialized expertise. For convenience and efficiency, we collected information that pertained to different objectives simultaneously. If we managed to arrange a meeting with a group of visually impaired children, we asked them about both their perceptions of light and about their experiences at museums (See Figure 7).

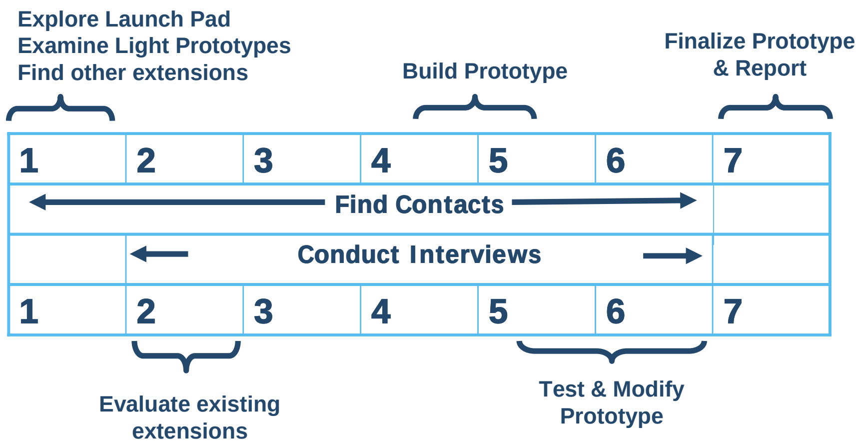

Figure 7: Timeline of Methods

3.1 Determine the Characteristics of Proposed Launch Pad Light Exhibits

Before we could proceed to any of the project's other objectives, we first needed to fully understand the exhibits that we were working on in the Launch Pad, which included: Mixing Colours, Light Table, and Periscopes. The major points focused on by these three exhibits were reflection, refraction, white light, and the color spectrum, all of which are discussed in the background chapter. We examined all available information about the exhibits including looking at models and asking museum staff who have worked with similar exhibits. We explained the proposed exhibit and the extensions to educators who work with visually impaired children in order to gain their perspective. By studying the exhibit from various viewpoints, the ambiguities in its ability to effectively communicate to the visually impaired were revealed.

The current model for each exhibit was examined. The concepts of light that each conveys, the methods used to communicate the information, and how compatible the exhibit is for people with varying types of visual impairments was recorded in the Exhibit Accessibility Evaluation Form found in Appendix E. Analyzing each exhibit using the form allowed us to see exactly which concepts were not being effectively communicated to the various types of visually impaired students. In total this process took less than a day to complete.

3.2 Identify and Evaluate Museum Adaptations for the Visually Impaired

To gather ideas, we evaluated current and previous extensions at the Science Museum, London and we also explored what adaptations other area museums had implemented. We collected data to determine what works well and what doesn't and ultimately applied that knowledge to the extension design. To determine the usefulness of an extension it was analyzed based on whether it is interactive or not, and whether the concept the exhibit seeks to portray can be revealed through the use of the extension.

3.2.1 Extensions at the Science Museum, London

We assessed the effectiveness of the extensions that have been in place at the museum, in a two-fold process. First we identified all current exhibits and programs in the museum that use some sort of assistive technology for the visually impaired, as recommended by current employees of the museum. We expected to find Braille, explainers, and audio supplements along with other types of assistive technologies. After identifying all extensions, we selected a representative sample, making sure to include each type of assistive technology that has ever been used and could apply to our project.

3.2.2 Techniques at Other Museums

So that we understood what other museums do, we held interviews with staff at other museums. This was done to find out what knowledge they had in their experiences of communicating to the visually impaired. We also talked to museum staff to find out what adaptations they use in their exhibits and explored the museum looking for assistive technologies that were not mentioned in the interview.

3.3 Determine Visually Impaired Children's Perceptions of Light

Before we developed the extensions for the visually impaired, it was important to be aware of how they understand light. By knowing their perceptions, we could communicate information to them in a way they could comprehend and at the same time we could attempt to identify and correct any common misconceptions the visually impaired have about light. To collect this information we interviewed educators who work with visually impaired children using the Perceptions Interview Protocol (Appendix I) and held focus groups with visually impaired children using the Perceptions Focus Group Protocol (Appendix H). The educators were able to connect us with the visually impaired students; it was ideal that we interviewed an educator, and held a focus group session with his or her students, while the educator was present so that an overall understanding of the students' learning style was possible. The educator's interview took thirty minutes and the focus group lasted an hour.

The focus group was set up as a lesson about, followed by questioning children about aspects of light, and then explaining the scientific phenomenon. We used the feedback from these sessions to modify the "lesson" of the protocol (Appendix H) until we were satisfied that it was effective.

On certain instances we simply asked the teacher of the visually impaired how their students' perceived light. Since we had only two months to accomplish this project, we also sought the knowledge of the teacher about the students. While meeting with these teachers, we also gathered information on the extensions. By asking their opinion for modifications to the extensions, ultimately the extensions would be more effective in communicating to the visually impaired.

3.4 Design and Build the Extensions

Designing and building the extensions was an ongoing process while at the museum. Using information gathered from the first three objectives, we developed prototype extensions. We then collected feedback on the extensions, similar to the Methodology used to improve the physics lesson, in which we noted desired changes and then revised and enhanced the prototype. To collect feedback on the extension, we examined each of the prototypes using the Explainers throughout the museum using Extension Evaluation Protocol (Appendix G). After a week of testing, the design was finalized.

3.5 Conclusion

Throughout the research stage of the project, we worked on developing prototypes for use in the Launch Pad, as well as recommendations for future development of exhibit accessibility. The prototype took into account similar attempts at extensions at other museums, utilizing their strong points and correcting weak points. In doing this, the London Museum of Science is hoping to become a leader in the interactive accessibility for the visually impaired and create a more educationally beneficial experience.

4. Results and Analysis

Through the processes outlined in the methodology, several interviews, a focus group, and analysis meetings were conducted both at the Science Museum, London, the Boston Museum of Science, New College Worcester, and Perkin's School for the Blind (Watertown, MA). The purpose of this data gathering was to develop a better understanding of how the visually impaired are accommodated in everyday society and in educational institutions. Museums and schools were the focal points of the research conducted.

4.1 Science Museum, London

To grasp what the museum currently has in place to communicate to the visually impaired, a study of various galleries was conducted. The museum contains exhibits featuring everything from *Medicine in the 18th Century* to *Exploring Space*. Our team studied the Launch Pad, which contains six categories including: light, materials, energy transfer, forces and motion, electricity and magnetism, and sound. Launch Pad focuses on creating an interactive learning experience for children. The Launch Pad is a hands-on inquiry learning atmosphere, which teachers and parents welcome. In particular teachers feel it gives pupils access to the types of experiences which are often difficult or too expensive to re-create in the classroom

4.1.1 Current Visually Impaired Extensions

It was found that the museum had minimal Braille written explanations for the visually disabled and some tactile models for general use by all visitors, including the visually disabled; for example, in the Mathematics gallery, there is an abacus for general use by the public. Much of the Braille used is for navigating around the museum, such as in the elevator, and not for specific exhibits or displays. Some of the interactive programs in Launch Pad have been modified so that the Special Educational Needs (SEN) groups could experience them in smaller groups with more explainers, but nothing yet has been specifically developed for the visually impaired.

4.1.2 Meeting with the former Disability Awareness Co-ordinator

A meeting with the former Disability Awareness Co-ordinatior, Katie Gonzalez-Bell who recently left to become an SEN Teacher, for the museum was conducted. A major part of the interview was learning the appropriate language regarding disabilities in the United Kingdom and what terms may be offensive. Often, there is a difference in meaning for certain words; for example, certain words and phrases used in the United States would be considered rude and extremely inappropriate in the United Kingdom (See Appendix O for a complete list of these words). Ms. Gonzalez-Bell also stressed that when speaking to the visually impaired it is important to indicate when you are leaving and arriving. Often the visually impaired are left alone when speaking to someone, and will continue a conversation because they do not know that the other person is no longer present. Mentioned also was the fact that it is a myth that the visually impaired have a heightened sense of hearing. This meeting communicated the proper language and techniques to use with special educational needs groups.

4.2 Boston Museum of Science

To explore what other science museums have done to communicate to the visually impaired, the Boston Museum of Science was visited prior to coming to London, and interviews were conducted with staff at the museum.

4.2.1 Tactile Methods

Tactile diagrams are often used to allow the visually impaired to feel their way around a map, graph, picture, etc. To make tactile diagrams, the planetarium at the Boston Museum of

Science uses “swell paper” made by the British company Zychem (Grice, Noreen, April 25, 2007). A grey-scale image is printed on the foam and then the foam is baked, causing anything darkened to pop up. The image can be copied with a photocopier, printer or even hand-drawn with a black pen or marker. The museum likes this method because the diagrams are easy to reproduce. These were used in the Planetarium for a show that studied the moon and the phases of the moon. The various types of space ships used to get to the moon, the phases of the moon, as well as other simple diagrams were created and distributed for use during the show. The Planetarium also created an audio explanation for the visually impaired to listen to during a show for further clarification or a description of what was occurring.

4.2.2 Heat Methods

The Boston Museum of Science uses heat in two exhibits but was not conceived as an assistive technology to aid the visually impaired. One exhibit, called *Hot or Cold* uses three metal plates, one hot, one room temperature and one cold. The other is called the *Weather Tunnel* exhibit. It uses ambient hot and cold to simulate different weather conditions. This exhibit was one that museum staff typically exploited when visited by a visually impaired person. The use of the sense of touch is one that when properly exploited is, in fact, effective in exhibits designed for the visually impaired.

4.2.3 Smell Methods

Smell has also been used at the Boston Museum of Science. “Smell Boxes” supplemented a variety of exhibits including one where the museumgoer connects a smell to a store. By trying to relate the smell of a bread shop to that of a pastry shop or that of a pie shop, the student interacts with the different types of smells one encounters in a day. The exhibit stressed the uniqueness of smell, almost as a fingerprint to the substance from which it originates. Smell's individuality makes it useful for museum exhibits.

4.3 Tate Modern Art Museum

To explore how highly visual subject matter was effectively communicated to the visually impaired, an interview was conducted with Marcus Horley, the director of accessibility at the Tate Modern. He also explained and conducted a "Touch Tour."

4.3.1 Touch Tours

The touch tours are four different guided tours developed for the visually impaired so that they can fully experience the art on display. Twenty-five trained general staff at the museum lead the visually impaired to five or six exhibits varying in genre. Tactile and auditory methods are used by the Tate Modern to extend the artwork to the visually impaired.

4.3.2 Auditory and Tactile Methods

Auditory methods consist of the leader describing the artwork, or comparing the artwork while the visually impaired "feel" the work's surface and thoroughly investigate the statues characteristics. Other tactile methods are used in addition to simply feeling a sculpture or painting. The visually impaired are given different props to help them understand the concepts and mood of the artwork, which include: fabric, stone, wood, brass, costume props, children's toys.

Figure 8: Claude Monet's *Water Lilies at the Bridge*

For instance, when viewing Claude Monet's "Water Lilies at the Bridge," the visually impaired are given very soft cloth, while the explainer describes the peaceful, sereneness of the painting or a fake water lily to give them an idea of what one is. The Tate Modern also uses the "swell paper," mentioned above, to create tactile versions of artwork that is simple in nature.

4.3.3 iMap

iMap, a useful tool for those with partial sight, is a computer program that simplifies and focuses on certain parts of a piece of artwork so that the viewer can understand how the piece was painted as well as the details within the painting. This is done by breaking down the picture into different segments and slowing adding the segments together to form the complete artwork. This enlargement and in-depth analysis in a simple form creates a forum through which those with partial or impaired sight can uniquely, but completely experience a piece of art.

4.4 Perkins School for the Blind

Museums and schools both have the common goal of educating the people who attend them; therefore investigating how schools modify lessons for the visually impaired was an important aspect to investigate. While museums and schools may not have the same methods for the pupils who attend them, the ultimate goal in each having the pupil learn something allows for the two to be sources for the other. Perkins School for the Blind in Watertown, Massachusetts has a history museum, a library, classrooms and other facilities, all of which are modified to accommodate the visually impaired. Both the Perkins staff and students were enthusiastic to help tackle the complications that arise when trying to communicate the properties of light to people with visual impairments.

4.4.1 Perkins History Museum

Betsy Miginity, the head of the history museum, stressed the importance of keeping the exhibits consistent. For example Braille is always on the left, audio on the right, and the tactile object(s) appear in the center. In the museum there is also a tactile map of the Perkins campus to help visually impaired navigate though the campus.

4.4.2 Perkins Students & Teacher Focus Group

A small focus group was conducted with Jen Nagarah, a science teacher for Perkins and some of her sixth grade students. The objective of the focus group was to determine how the visually impaired perceived the properties of light as well as to establish ways to relate light to phenomena that someone with severe visual impairments could experience. Ms. Nagarah explained that while they try to keep up with the curriculum of mainstream schools, it is difficult because there are fewer teaching resources designed for the visually impaired dealing with science. One student who has been blind since birth described "reflection occurring when an image appears somewhere else." The students could not explain what a shadow was, but they did have an idea of light versus dark, with a basic understanding of light intensity.

Ms. Nagarah thought that relating light to sound or heat was an excellent idea. A partially sighted student suggested that the intensity of light can relate to the intensity of sound where high-pitched is bright and low-pitched is dark.

4.5 Royal National Institute for the Blind at New College Worcester

To understand how the blind are taught at a higher level of learning, an interview was conducted with Chris Stonehouse. Dr. Stonehouse currently teaches A-level physics and the sciences to the visually impaired at New College Worcester. He also is the Director of Studies for the college.

4.5.1 Visually Impaired Educational Tools

To accommodate the educational needs of the visually impaired, some special schools have been operating in the United Kingdom. The school also aids in the education of the visually impaired in mainstream schools. Unique tools such as Drawing Film, Light Meters, Color Identifiers, Braille labels, large print booklets, and Blue Tac were used extensively at New College Worcester.

Drawing Film, commonly referred to as "German Paper," is a thin plastic sheet. When drawn on with something as simple as a ballpoint pen, the film creases to leave a raised line along the path of the pen. It creates a tactile version of whatever is written on the paper. It is used for everyday class exercises and exams to draw graphs and conduct experiments.

Light Meters and *Color Identifiers* are used during science experiments. The Light Meter makes a tone that increases and decreases with the intensity of the light. Color Identifiers verbally name the color that it is placed against.

Figure 9: Light Meter

Braille labels and *large print books* are in use throughout the school. Bulletin Boards use Braille labels as well as directional signs throughout the campus. The Library is filled with large text and Braille versions of many books.

Blue Tac is a putty like substance that when placed on a surface will stick to the surface. The substance itself does not stick to the human hand but will to other materials. The visually impaired students use this material for tracings or markings when completing schoolwork.

4.5.2 General Techniques for the Education of the Visually Impaired

The complexity of diagrams, raised pictures, tactile displays, and other tactile objects needs to be simple and large to effectively communicate to the visually impaired.

Figure 10: Tactile Map of Edinburgh, Scotland

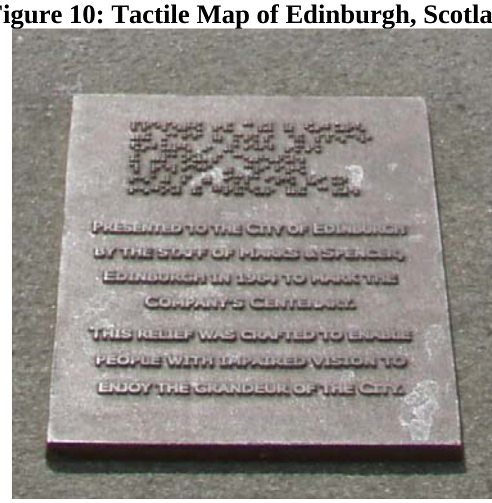

Figure 11: Plaque for the Edinburgh Tactile Map

For example above, this raised map of Edinburgh, Scotland, clearly depicts the surrounding area including the buildings and landscapes, with accompanying Braille text. Auditory versions of books and text need to have steady and clear speech. When using auditory methods, loud noises are perfectly fine; however, loud unexpected noises should be avoided.

Dr. Stonehouse explained that when teaching any subject, it is useful and usually necessary to present information in different forms that complement each other. When several different means of communicating a concept are presented, it will more likely be clearly understood. Finding links, analogies, and models are the key to success.

The same tools used to teach sighted students in mainstream school can and are easily adapted for the visually impaired. The use of Braille labels is typically the only required adjustment. At the New College Worcester, they created a tactile periodic table, because the periodic tables for the visually impaired have only been lists in the past. With a tactile version, students get the full experience that all mainstream students have. That is they can “see” what a period or a group is, the line that separates metals and non-metals, as well as understand the electron orbital theory. All of these ideas are lost if the elements are simply listed.

Figure 12: Tactile Periodic Table

When visually impaired children are in mainstream school, it is recommended that the teachers do not adapt everything for the visually impaired. If a teacher typically uses a PowerPoint presentation for the general class, it should still be used; however, the visually impaired student should be taught using another learning method to compensate for the fact that the visually impaired student cannot experience the PowerPoint presentation.

4.5.3 Light Experiments at New College Worcester

Dr. Stonehouse demonstrated a few experiments which he performs with his students that display the properties of light. One experiment was with shadows and used a light source, an object and a large sheet of thin paper arranged in that order. The object would block the light source, creating a shadow on the paper.

Figure 13: Shadow Experiment

Using the light meter, the students could trace the object from behind the paper, so they do not block the light. A simple shape, such as a square, would be easiest as it has distinct edges and is recognizable. Once the shadow was outlined with Blue Tac the object would be moved closer to or farther away from the light source. The students would again outline the shadow, finding out how it changes in size. This concept is more easily explained once the students participated in such an experiment, because they tactilely recognize how shadows change based on distance and position of the light source.

Another experiment Dr. Stonehouse conducts uses the same concepts as the shadow experiment but with lasers shining on the paper. The students stand behind the paper and use the light detector to find the spots where the laser was shining. The beam could be diffused using different lenses, and the students have to find where it hits the paper. This makes it easier to teach the knowledge related to lenses and their properties.

The last experiment that was performed used a light box where a bright light source in a case shined horizontally out in one direction. With this, different lenses and cut-outs are placed in front of the light source and shine onto a piece of German paper that is on the table next to the light box. Students are able to mark where the light is at several spots using the light meter. Then using a tactile ruler the students connect the marks with a line, displaying the lights path. This shows the difference in lenses, but in a more tactile way as the German paper creates a tactile diagram of the light path, aiding the lesson.

4.6 Evaluations of the New Light Exhibits

We analyzed two exhibits, specifically *Light Table* and *Periscopes*. These exhibits relate unique phenomena of light. These were studied and analyzed looking for analogies that would exploit the tactile or auditory senses.

4.6.1 Light Table

Light Table focuses on the manipulation of light using prisms, filters, mirrors, and glass. Having three stations around the table, there is a specific activity in each area of the table.

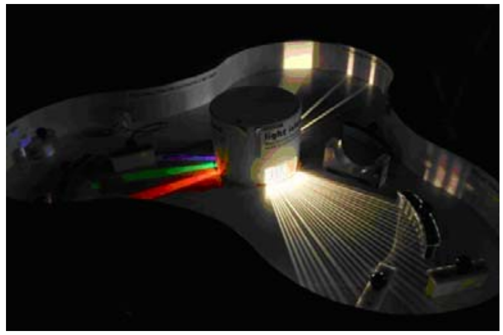

Figure 14: Light Table Exhibit

4.6.2 Periscopes

The periscopes exhibit focuses on the bending of light and demonstrates different uses for this property. A wall is in place which has a periscope that allows a visitor to see another visitor on the other side of the wall. Mirrors and the reflective angles are the central theories portrayed by this exhibit.

Figure 15: Periscope Exhibit

4.6.3 Accessibility for the Visually Impaired

In general, there is little interactive accessibility currently in use for the visually impaired at the museum. Adaptations to some of the interactive shows within the Launch Pad has taken place, but the actual exhibits in the Launch Pad area as well as the museum in general currently have little available for the visually impaired. The interviews and focus groups discussed above led us to decide that the use of tactile and audio means would work best for teaching the visually impaired. With this approach we were able to developed ideas for the prototypes.

5. Conclusions and Recommendations

This project researched ways to make the Launch Pad Gallery light exhibits accessible to people with visual impairments, specifically to develop extensions for the periscope and light table exhibits. The challenge of the project was to find a way to conceptualize the phenomena of light in an interactive learning experience for those with visual disabilities. The prototypes had to demonstrate the phenomenon of light portrayed in the exhibits without losing the interactive aspect of the Launch Pad gallery. Prototypes for these exhibit extensions were designed based on interviews with teachers of the visually impaired, interviews with other museums' accessibility directors, and literary research on visual impairments, assistive technology for the visually impaired, and the education of the visually impaired.

The periscopes exhibit demonstrates reflection by using mirrors to redirect light underneath a wall so that what is on the other side of the wall will appear in the periscope. To simulate this, the periscope exhibit was scaled down so that it had the same principles as the large exhibit, just in miniature form; that is the extension will still focused on the principles of reflection and the experience of bouncing light around a solid object.

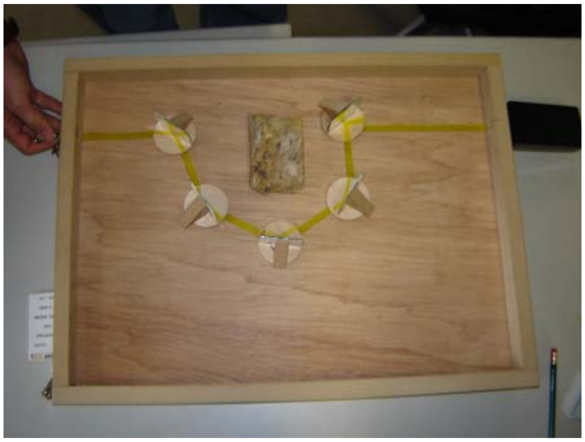

Figure 16: Periscopes Prototype

Visitors turn several mirrors to aim light in order to reflect it around an obstruction. The path of the light is tactilely represented by a raised path and can be followed when the mirrors are aligned. Also, a light detector will sound when the light reaches the final position (see Appendix P).

Figure 17: Light Meter

The restrictions of this prototype were caused by time constraints. We recommend in the actual construction of the extension that the mirrors should have four settings and not just be free moving. This would make the "challenge" more practical, as there would no longer be infinite ways to complete the path. Also, the detail of the light path could be improved by the mirrors being flush mounted with the surface of the box. This would allow for the user to feel the path on a smooth surface, as opposed to being raised up at certain spots, and not creating one smooth solid line for the light path. A light could be used instead of a laser, so the path of light could be seen visually by those without disabilities or with limited sight could appreciate the concept being illustrated by the extension.

The light table demonstrates white light and how it consists of all the colors of the visible spectrum. Because of the similarities between the visible light spectrum and the auditory range of sound, the analogy between the two phenomena works well for explaining light to the visually impaired. An interactive "flash animation" was developed that works together with a control box attached to the computer. Flash is a computer program capable of combining sound and a control box together. The control box has 7 buttons, 6 that represent each color, and one to start the audio prompt (see Appendix Q).

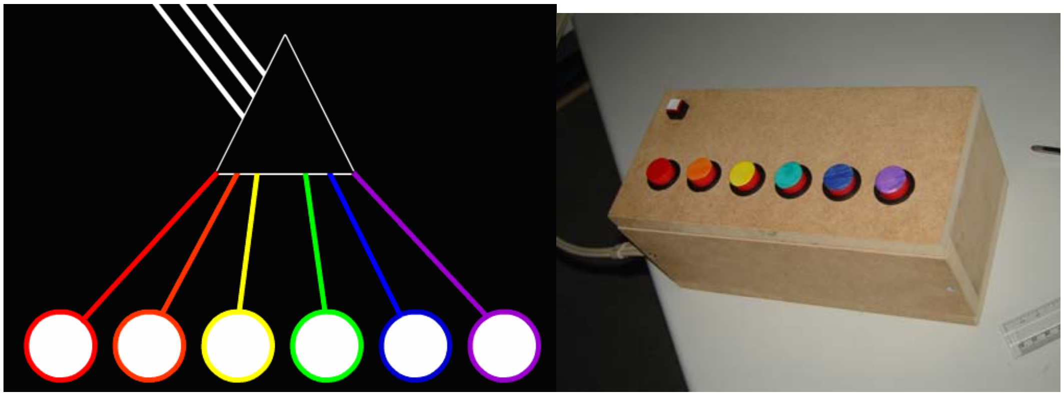

Figure 18: Light Table Prototype - Computer Screen and Control Box

When each button is depressed it plays a tone that corresponds to a color, that is, each color is assigned a different tone in the analogy. As more buttons are pressed, the tones combine to create a new and different sound that is a combination of the originals, just as the combination of the visible spectrum creates a new and different "light". This allows the user to interactively learn that white light is actually composed of the colors of the spectrum (different tones in the extension) and allows them to make new tones through combination, simulating the process of creating new "colors." The limitations of this prototype include the fact that unlike set tones, light has no clear divisions. We selected the colors that are taught to students in grade school as the colors of the rainbow. Within the light spectrum, the colors we selected are not clearly defined, and would not technically combine to form white light, because white light is the combination of the entire color spectrum. The next step in the development of this prototype would be to create a portable version that would utilize a prompt type format and would have a screen that would illuminate with the color that would be created by the depression of the various colors. As of right now, our prototype requires the use of a computer for the program to work, the development of a computer-free prototype so that the extension could be kept on gallery is why it must be portable. For the technical aspects to the design of the white light prototype see Appendices O and P.

Along with these two prototypes, a versatile tool for light experiments and demonstrations was designed and built; this light meter converts light intensity into tone pitch. This device can be used to detect shadows, show light intensity or to tell if a light is on. These concepts were developed as a result of the research done over the past three months, including technological knowledge drawn from our various educational training.

The visually impaired rely on audio and tactile means to experience the world; therefore, the prototype for reflection was based mainly on tactile means of communication and the colors prototype is based on an audio signal. Many options were available for designing these prototypes but we believe our design best meets the educational criteria discussed above concerning clarity and interaction for the Launch Pad gallery criteria.

In generally, there are several things the museum can do to improve their overall accessibility for the visually impaired, which include Braille labels, audio explanations, tactile diagrams, and explainers who are trained specifically to guide visually impaired visitors.

Noreen Grice, from the Boston Museum of Science, and Dr. Stonehouse, from New College Worcester, say that grade-one Braille is adequate for short labels. However not everyone with a visual impairment can read Braille, so audio explanations are a more universal way to relay information. Audio explanations make the exhibit more accessible to not only those with visual impairments, but also visitors who cannot read.

Swell foam is the most common and easiest way to create tactile diagrams of simple images. The Boston Museum of Science, the Perkins School for the Blind, the Tate Modern, and the National Institute for the Blind at New College Worcester all use swell foam. Swell foam is popular because it is easy to reproduce images and the images are visible for those who can see. The RNIB sells 200 sheets of swell foam for 125 pounds and the machine to heat the paper costs between 290 and 700 pounds depending on the model of the machine. Swell foam can also be used to create freehand images; the paper will rise when it is drawn on by a special heat pen. If the museum needs to produce freehand or graphics that are drawn on-the-fly, they can be produced with German film. German film only needs a general pen and a rubber pad to work, and created tactile diagrams in a matter of seconds. Either of these methods would enhance the museum experience of those with visual impairments.

The Tate Modern and the Boston Science Museum have trained staff to guide blind people through exhibits that were not originally designed to be accessible to the visually disabled. The guides show the visually impaired around the museum and help them have a fulfilling visit. The British Museum currently allows only visitors with visual impairments to touch the displays. With supervision, the Science Museum, London could allow visually impaired visitors to touch items normally behind glass or not in reach of the general public.

For more complex exhibits that cannot use swell foam, the museum should also invest in three-dimensional models to be placed at the exhibit. At the Cathedral Church of Christ and the Blessed Virgin Mary in Worcester, there is a tactile model of the entire exterior of the church as well as of the interior of the church. Creating models helps visitors to understand the overall concepts being portrayed as well as develops a unique way to experience an exhibit for everyone.

Summary of IQP Experience

"Laws were broken, Hearts were broken, and Noses were broken"

Our stay in London was very eventful and fast paced . We saw all of the major sights to see: Big Ben (which is actually St. Stephen's Tower), Parliament, Westminster Abby, St. Paul's Cathedral, Buckingham Palace (even the gardens), British Museum, History Museum, Science Museum, National Army Museum, Imperial War Museum, Royal Observatory, Prime Meridian, Tower of London, London Eye, Cleopatra's Needle or as we like to refer to it as "The Thimble", and Soho. For the relaxing part during our stay in London we spent a great deal of time in St. James's Park, Hyde Park, and Battersea Park. The majority of our time was spent in St. James's Park however. We frequented this park so much that we had a real football sent to us so we would have something to do while we were basking in the sun. One thing that we discovered was that the weather in London is not good for getting a tan. The weather of England has to be the most sporadic in the world, and that is including New England weather. It can go from being sunny and hot to cloudy and cold then to rain all in about 20 minutes.

As for getting around in London, we got our money's worth out of our "tube" passes. There were many times at the beginning of our trip in London where we had no idea where we were going so we would just get on a bus no matter what direction it was going in. After a couple of minutes at looking at our map, we would realize that we were going in the total opposite direction that we were supposed to and we would get off and turn around. There was one time that we felt that we were at the end of the line so we felt that we would just stay on the bus and it would eventually turn around, bad idea. The bus never turned around and we ended up going a lot farther than we expected to go.

Some of the culture that we experienced was not so good. For example if you ask for directions and you are American, any English person will point in one direction and say "you go five minutes down the road and take a left."

London may have had its high points, but the highlights of the trip were our "holidays" out of the city. We traveled to Rome, Dublin, Edinburgh, and one of us will continue in Amsterdam. While we never traveled as a complete group, the trips were once in a lifetime experiences. The gothic nature of Edinburgh, the eternal grandeur of Rome, and the cosmopolitan mixture that is Dublin all made our weekends the best. The culture of Rome out of all the cities we have been to was the best. The rich history alone is immense. While there we saw the Coliseum, the Roman Forum, St. Peter's Basilica, the Sistine Chapel, the Fountain of Trevi, the Vatican Museums, and the Spanish Steps. Our nightly routine in Rome after a day's worth of sight seeing would be to go to a local market and purchase fresh mozzarella, prosciutto, fresh bread, an of course wine. There is no other place on the face of the earth where it is impossible to have a bad meal. The food we had consisted of pizza with various toppings, sandwiches, and most important pasta. Our trip ended with us walking along a highway to have the best meal of our lives only to walk back to the airport to find out that we could not sleep in it. Because of this the only place to sleep was on the sidewalk. It was definitely an interesting experience.

Our last couple weeks in London have been quite boring compared to the previous weeks. This is not to say that we were not working those first few weeks, but that the heavier part of the writing for the IQP report did not arrive until we were well into the project. Those first couple of weeks mostly consisted of nightlife and afternoons in the park. Our favorite nightlife spots would have to be Zoo bar and O'Neil's. We have had many fun nights at these spots. The stories that we could tell from these bars would probably be as long if not longer than our IQP report.

Our project was also a fun experience. Getting to work in the Science Museum London was a blast. There was always something to do when we got bored. We didn't just have fun however, we had lots of long days of writing, researching and designing. But we were always able to lighten those days up by talking with Caroline, who worked in our office. And how could we forget Rachie; she put up with all of our questions and mischief. From the trips to Worcester, England with the birds and the stickers to the endless meetings, there were also endless good times. The premier educational center for the visually impaired is in Worcester, England. One day we took a trip to this school, while there Rachie and Galia both sat in the wrong spot below a bird, we will leave your imagination to figure out what happened. We also discovered that Rachie has an immense fear of stickers, and we of course exploited this fear. We did actually accomplish our task of creating two prototypes for the new Launch Pad exhibit. Our first was an exhibit that allowed the visually impaired to feel and manipulate the path of light as it was bounced around a solid object. And the second was a button box that connects to the computer and plays tones that correspond to each color of the light spectrum. These prototypes would not have been completed if it was not for the help of the computer programmers on the 3rd floor and the shop guys in the basement. They put up with all of our changes and had our prototypes looking like a real extension. Overall we had a great experience in London, filled with loads of fun; however, we are glad to be returning to our homes exhausted and grateful to our British hosts, and as our liaison said "London will be sighing a cry of relief" as we make our final exit.

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Appendices

Appendix A: Information on the Science Museum, London

The Science Museum, London officially opened in 1857 as the South Kensington Museum; however the museum has its roots in the Great Exhibition of 1851 (National Museum of Science and Industry, 2007b). The original museum stood where the Victoria and Albert Museum now stands. Originally the museum's focus was on the industrial and decorative arts, but throughout its early existence there were exhibits on technology and science, principally biology and anatomy.

By 1860, the science and technology aspect of the museum was becoming increasingly popular and space consuming (National Museum of Science and Industry, 2007a). The buildings built across from the South Kensington Museum, specifically build for the Exhibition of 1862, were taken over by the museum and converted to the science and technology section of the museum. In 1876, an exhibition entitled "Special Loan Collection of Scientific Instruments" was held at the South Kensington Museum (National Museum of Science and Industry, 2007b). This exhibit made the museum an internationally known and respected institution as well as increased the total number of artefacts owned and displayed by the museum.

In 1883, the Science Library was added to the museum, as well as all of the contents of the Patent Office Museum were formally transferred to the South Kensington Museum (National Museum of Science and Industry, 2007b). In 1989, HM Queen Victoria laid the cornerstone for the Victoria and Albert Museum, which in the original plan was to continue to contain the Science collections. When the museum opened in 1909, the Science Museum, London was finally recognized as its own entity. The need for a new building for the Science Museum, London was immediately recognized. Begun in 1913, the first of the Science Museum's buildings, did not fully open until 1928 due to the First World War (National Museum of Science and Industry, 2007a).

Although the museum was new, it had serious public relations trouble. The Museum catered to those with previous knowledge of the objects presented. The museum was quickly changing and was becoming designed for “the ordinary visitor.” The museum opened a children’s gallery at the end of 1931 – this is the ancestor of the Science Museum’s current children’s gallery called the “Launch Pad” (National Museum of Science and Industry, 2007b).

Throughout the museum’s history it was a state owned and controlled entity. However, in 1984, the museum as well as the Victoria and Albert Museum, were removed from control of the United Kingdom government and were placed under the control of a Board of Trustees (National Museum of Science and Industry, 2007a). The museum has since been run by a Director in charge of various departments. The Museum still is funded through government grants, however control and running the museum is no longer the responsibility of the government.

Since its creation, the Science Museum’s goal has been to relate modern technology and science to the general public. With the modern era of anti-discrimination and increased awareness of equal opportunities, the museum’s current issue is to be able to relate all museum exhibits to the disabled. Within the past few years London and the UK at large have passed several laws pertaining to the creation of extensions and the remodelling of buildings to suit the needs of the disabled community (DirectGov, 2007). The Science Museum is currently seeking to find new technologies and systems to relate their exhibits to the disabled.

The Science Museum is not the only museum and building in London working on this problem. Its sister museum, the Victoria and Albert Museum, as well as the Charles Dickens

Museum, and many other museums throughout London, are working to improve their public relations, by creating extensions for the disabled community.

Appendix B: What is an IQP and How does our Project Qualify as an IQP

An Interactive Qualifying Project, or IQP for short, as described by Worcester Polytechnic Institute (2007), is "a project which relates technology and science to society or human needs." The goal of the project is to have students learn by doing hands-on work and to ultimately propose and design a solution to a real life societal problem. The problem statement and objectives for our IQP as communicated by Science Museum, London (2007) were as follows:

> *The London Museum of Science is redeveloping their Launch Pad gallery, which is a hands-on gallery that uses mechanical interactives to provide visitors with the opportunity to explore real phenomena. One of the key aims of the new Launch Pad gallery is that the mechanical interactives are accessible for disabled visitors, allowing visitors with a wide variety of needs to interact and explore the central phenomena. One approach to achieving this goal is to provide "exhibit extensions." These extensions will consist of tools and materials that will support people with specific disabilities to investigate the phenomena, for example visually impaired visitors to explore the light exhibits. This is an innovative area of interactive design in which the Science Museum intends to be the world leader and it will contribute to the Science Museum's overall aim to make its galleries as accessible as possible for disabled visitors. The Science Museum is keen to learn more about how to design effective exhibit extensions for visitors with disabilities. Due to the particularly challenging nature of the topic, the Science Museum would like to focus on exhibit extensions for exhibits in the 'light' area which will help people with visual impairment to investigate the phenomena. This will include people with limited sight and people who are considered completely blind.*

This project qualifies as an IQP because it is an engineering project that deals with a societal issue, the accessibility of the visually impaired at the Science Museum, London. In our project we researched visual impairments to gain an understanding of the environment and people we were working with. We combined our technical knowledge with educational techniques used to teach scientific concepts to the visually impaired, which allowed us to design prototypes for the visually impaired to interact with an exhibit and not be excluded from the museum experience because of their disability. Through this we learned to assess a real world problem with technical, social, and humanistic dimensions and to find a solution by a group effort.

Appendix C: The Process of Seeing – Normal Eye Function

The general structure of the eye is:

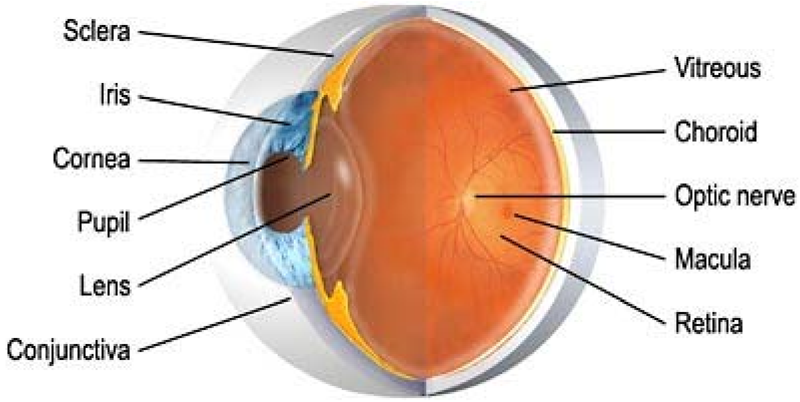


Figure 19: Eye Structure
(St. Luke's Cataracts and Laser Institute, 2006)

The process through which an object is seen occurs by the following method: light rays travel to the eye, and are bent by the cornea, lens, and vitreous (St. Luke's Cataracts and Laser Institute). The bent light rays are focused on the retina. The image that appears on the retina is upside down. This is displayed in the following image:

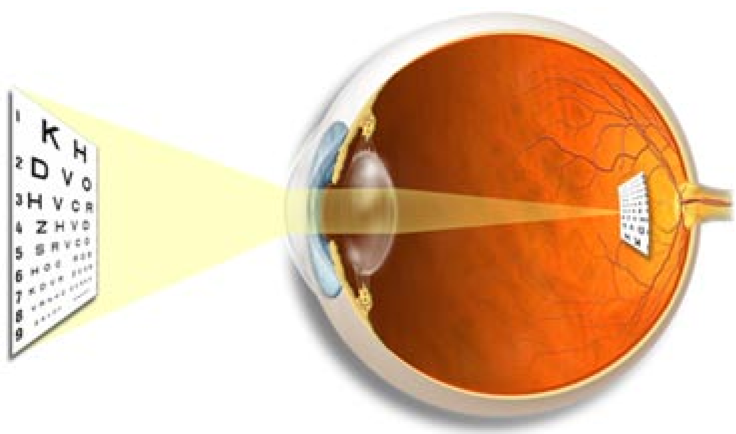


Figure 20: Seeing Process
(St. Luke's Cataracts and Laser Institute, 2006)

Here the image is converted to electrical impulses that travel through the optic nerve to the brain where the electrical impulses are decoded and flipped to give the proper image. The macula is the most sensitive area in the retina. Used for reading and other functions where the eye is focused, it is the most used part of the retina (2006).

Appendix D: Types of Visual Diseases

Refractive Errors

The three types of refractive errors are Myopia, Hyperopis, and Astigmatism. All three can be corrected by glasses, and as such are generally overlooked as needing to be catered for by the general community.

Myopia

Commonly referred to as Nearsightedness, this is caused by an elongated eyeball, a lens that is too strong, or a cornea that is excessively curved (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). This results in the image from distance objects being focused in front of the retina. The person can clearly see things that are close, but distance objects appear blurry and distorted.

Hyperopis

Commonly referred to as Farsightedness, this is caused by a short eyeball, a lens that is to weak, or a cornea that is too flat (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). Images are focused behind the retina with these deformities; causing objects at far distances appear clear and precise, while close objects are blurry and lack a solid form.

Astigmatism

This is eye condition is the combination of Myopia and Hyperopis (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). The result is the cornea has a cylindrical curvature, which does not focus light in any single place. The result is that all objects appear blurry, whether close or at a distance.

Eye Conditions

There are several forms of eye conditions that can cause visual impairment. Some can be corrected by glasses, other require surgery, while others have no known cure.

Albinism

While Albinism is not usually associated with an eye condition, the person with this condition lacks pigment throughout the body, resulting in an extreme sensitivity to light (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). Albinism is most usually associated with refractive error and Nystagmus, all of which can be corrected by glasses, tinted lenses, and the discovery of the null point.

Amblyopia

Commonly referred to as “Lazy Eye,” is the result of one eye having a significantly lower acuity (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). Solved by the use of an eye patch for a period of time, or the use of glasses to increase and eye’s acuity, this problem usually disappears during childhood, although it is not unheard of for a “Lazy Eye” to be present throughout a person’s life.

Cataracts

Caused by a cloudy lens, the eye cannot accurately depict light, define color, or it can cause Nystagmus (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). This can occur in both eyes or a single eye. This can be either a birth defect or a condition that appears over time; both cases will sometimes remain unchanged with time, or will worsen with time. Glasses can be prescribed to correct the problem, or depending on the severity of the cataracts, surgery could be recommended to remove it completely. Cataracts are related to the normal aging process, but it can also occur as a byproduct of the German measles (Rubella) (Matsuoka, Luxton, & Rogers, 2001).

Coloboma

This is a birth defect which can result in permanent blindness (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001) which consists of a cleft in the pupil, iris, lens, retina, choroid, or optic nerve. If the cleft appears in the retina, permanent vision loss occurs.

Color Blindness

A hereditary abnormality of the retina, it is caused by a deficiency or surplus of the visual pigments in the retina (Newell, Frank W. 2001). It can develop by the ingestion of poisons, optic nerve disease, or diseases that destroy parts of the retina; there is no cure or way to correct this damage. People with color blindness can sense color to a point, color blindness means that they cannot see distinct colors.

Glaucoma

Tear ducts and the eyes themselves contain fluid. If this fluid places extreme pressure on the eye, glaucoma will occur (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). Commonly caused by some form of a blockage in the fluid flow, this can result in decreased peripheral vision, night blindness, and light sensitivity. If the condition is left untreated, permanent damage to the optic nerve will result which can result in any number of visual impairments.

Macular Degeneration

Always age related, this accounts for nearly thirty percent of all bilateral blindness according the National Society to Prevent Blindness (Matsuoka, Luxton, & Rogers, 2001). Related to the breakdown of the blood supply to the macula, the buildup of blood cells behind the retina, eventually cause it to detach and as a result, cause blindness.

Nyctalopia

Commonly referred to as Night Blindness, this condition allows a person to see fine in normal daylight or in room lighting, but they have poor vision at night or in dim light (Newell, Frank W., 2001). While this can be permanent, it is typically caused by a deficiency in Vitamin A and if caught early, a diet high in vitamin A can correct this problem.

Nystagmus
This is an involuntary movement of the eyes, which cause an inability to focus on any one object, and can also result in fatigue (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). This occurs from birth, and usually in childhood, the “null point” is found. The “null point” is a position of the eyes or head which results in a loss of the involuntary movement. The “null point” differs from person to person.

Onchocerciasis
A parasite infection caused by the bite of a black fly, in which a worm is transferred to the human, and then enters the blood stream (Matsuoka, Luxton, & Rogers, 2001). The worm then produces larvae that travel to the eye and the larvae then proceed to destroy any and all aspects of the eye. No cure for the disease is known, but simple spraying of creeks and rivers where the black flies live has decreased the number of occurrences in recent years.

Optic Nerve Atrophy
This condition results from damage or degeneration of the optic nerve so that information cannot fully be passed from the eye to the brain (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). This can cause blurred vision to blindness depending on the extent of damage to the nerve. No cure is available.

Optic Nerve Hypoplasia
An underdevelopment of the optic nerve, results in it being small (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). While the degree of visual impairment differs dramatically, the usual result is blindness. This can occur in just one eye; however, typically it is associated with both.

Retinitis Pigmentosa
A hereditary condition resulting in “tunnel vision” – the loss of peripheral vision, this condition usually starts with the loss of the ability to read in dimly lit areas to significant visual impairment, and is caused by a degeneration of the retina (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001).

Retinoblastoma
This is a cancerous tumor that appears in the retina (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). Treatment can vary from lasers, radiation, or chemotherapy. If the eye is removed, the loss of depth perception occurs in the remaining vision.

Retinopathy of Prematurity

Occurring early in life, this is the hindrance of normal development of blood vessels in the retina, resulting in scarring or detachment of the retina (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). This can cause both refractive errors and a loss of visual acuity.

Strabismus

When muscles do not develop to the same degree, the result is the inability of eyes to focus on the same object at once (New Hampshire Agenda for the Education of Students with Visual Impairments Goal One Committee, 2001). One eye will always have a specific turn relative to the other; the result is a need for a special form of glasses to correct the error.

Trachoma

The most common of all infectious eye diseases, Trachoma is a bacterial organism that inflames the cornea and conjunctiva (Matsuoka, Luxton, & Rogers, 2001). Generally found in unsanitary conditions, this form of blindness is typically found in developing areas. While treatable, if the bacterium is allowed to infect the eye several times, permanent scarring of the conjunctiva lining, which will eventually cause blindness due to repeated damage to the cornea.

Xerophthalmia

The primary cause of childhood blindness – particularly in developing countries (Matsuoka, Luxton, & Rogers, 2001). Caused by a deficiency in vitamin A, Xerophthalmia forces the conjunctiva, cornea, and retina to not develop to maturity. Five hundred thousand cases of blindness are associated with this vitamin A deficiency, and some five to ten million cases of visual impairment. Eating foods rich in vitamin A, and high protein diets is the best way to avoid this form of blindness.

Appendix E: Exhibit Accessibility Evaluation Form

Exhibit Accessibility Evaluation Form

Concepts to be Communicated (circle all that apply)

Sources	Propagation	Incandescence	Luminescence	Light Wave
Reflection	Refraction	Shadow	Color	Light Speed
Dispersion	Visual Spectrum	Lenses	Pigment	Subtractive Colors
Filters				

Methods (list concepts which are portrayed using each method)
Visual

Tactile

Sound

Other

Accessibly (list concepts which are not communicated to a person with each type of VI)
Color Blind

Tunnel Vision

Glaucoma

Low Vision

Blind

Other

Appendix F: Exhibit Extension Evaluation Form

Exhibit Extension Evaluation From

How much vision do you have?

What did you like about the extension?

What could be improved?

Appendix G: Extension Evaluation Protocol

The participants should have some level of visual impairment. If this is with a teacher, we will ask him of her the same questions. This should take 30 minutes

>Introduce ourselves
>Explain our project
How much vision do you have?

>pass the extension around

What strikes you about this?

Does this demonstrate anything to you? What?

>If it has not been pointed out, explain the major thing they were supposed to notice, e.g. "A weight hanging from the far end of a beam causes the beam to bend more than if the same weight were hung from the middle of the beam."

What aspects of the model effectively communicate the desired lesson?

What could be improved?

Appendix H: Perception Focus Group Protocol

Perception Focus Group Protocol – 1 hour

>Introduce ourselves
>Explain our project

How well can you see? [Ask teacher about each student beforehand]

>After each of these questions we explain them in "VI friendly" terms, and then gauge the effectiveness of our explanation

What do you think light is?
What do you think the dark is?
A good way to compare light and dark is hot and cold. If you are outside in the sun it's both hot and bright out. In the winter it's dark and cold

What do you think makes light?
Light sources produce light in two ways

Incandescence and luminescence. Incandescent light is only produced by very hot things – such as the surface of the Sun, part of a flame, and the element inside a toaster.

Luminescence occurs when charged particles move from a high-energy state to a lower one. [Will they know about atoms?] The energy has to go somewhere, so it's released as light

Light moves as a wave. What do you think a light wave is?
Sound is lot like light. They both travel in waves and have a source. Like sound waves, you can't feel them as they go through the air [Bring out simple tactile diagram of a wave].

What is a mirror? How does it work?
A mirror reflects light.

What do you think a reflection of light is?
As we've said, light is a lot like sound. A reflection is like an echo.

How might a reflection be like an echo?
A reflection happens when the light wave bounces off something. An echo happens when sound waves bounce off a surface.

Some materials absorb the light wave rather than reflecting them. What do you think absorption of light is?

What do you think refraction of light is?
Reflection is one way to make light change direction. But light also changes direction whenever it passes through one transparent material to another. This bending of light is called refraction. Refraction happens because light travels at different speeds in different transparent media. For example, the speed of light in water is faster than in glass, but slower than in air.

What to you think a shadow is?
Imagine you are out in the sun or near a very hot source of heat. Then some object comes between you and the heat. What happens? [Expected answer: it gets colder] Right, it gets colder.

Do you associate anything with any colors?
Do you associate “hot” with any color?
Do you associate “cold” with any color?

Appendix I: Perceptions Interview Protocol

To be conducted with teachers of the visually impaired. Should take 30-60min

>Introduce ourselves
>Explain our project
How did you come to work with the visually impaired?

Do you think that there is a lack of resources when it comes to teaching the blind and visually impaired about science? Why or why not?

We're wondering what your experience has been with science education, especially light. Do you teach about:

How light is created?
How it moves?
Why things are different colors?
Reflection or refraction?

If yes, ask how they teach.

We are curious about how children with severe visual impairments think about light.   Could we conduct a focus group with your students to find out what they think?

We've prepared a lesson about light. We tried to keep everything in VI friendly terms. Hand them the lesson.
Could we run this by you? Your input would be very much appreciated.

May we conduct this lesson with a group of your students?

Do you know any other teachers whom we could talk to?

Appendix J: Interviews at the Perkin's School for the Blind

Betsy Miginity - Head of the Perkins History Museum
Alexa Kontes - Librarian for the student's library (alexa.kontes@perkins.org)
Jen Nagarah – Science teacher at Perkings (jen.nagarah@perkins.org)
Kerryne – Student. Blind since birth, but can tell if it's light or dark out. (617-972-7405)
Cara – Student; can see colors.

First contact = Betsy Miginity
Does not teach or deal with children
Recommended *Art Beyond Sight* and other books in the Perkins Research Library
Recommended Smithsonian Guidelines for Accessible Exhibition Design (webpage)
Be specific. Make reference to a clock face. "Potatoes at four o'clock"

Showed us the history museum.
Pointed out:

- the constancy of each exhibit. (Braille on left, audio on right, tactile in the middle)
- Tactile map of the Perkins Campus.
- Display of a math book; used a thread through cloth to "draw" the shapes.

Betsy recommend we talk to Alexa Kontes, the librarian for the student's library.

Alexa Kontes works with children, but not much with science and didn't keep the science books in the library. So she made a few phone calls and had Jen Nagarah, the science teacher come in with her books and also two students, one who has been blind all her life but can tell if it's really bright out or dark out (Kerryne) and one who has partial sight and can see colors (Cara).

Jen: We try to keep up with the curriculum, but there are less science recourses. People think the VI can't learn science.

They all agreed that exhibits text needs to be supplemented with audio, Braille and large print.

James?: Have you heard of reflection or refraction?
Kerryne: I've heard of reflection. It's where an image appears somewhere else.
Galia: Light works a lot in the way that sounds works. A reflection is a lot like an echo. Does that makes sense?
Kerryne: yes (NOTE: I'm not sure if she really did understand it or just acted like she did)

James?: What do you think a shadow is?
Kerryne: I'm not sure
Galia: Think about being in front of something very hot. That is like the light source. Now if an object goes between you and the hot thing, it feels cooler, right?
Kerryne: yeah
Galia: It's the same idea with light. The light is blocked by something so it's darker

Kerryne: ooooh (again, NOTE: Not sure if she really did understand it or just acted like she did)

Jen: was excited about using heat to show properties of light.

Cara: relate the intensity of heat/light to sound. High-pitched is bright and low-pitched is dark

Alexa: glare makes it had for partially sighted people to see

Alexa (to the girls): Are there any colors that make you think of anything?

Kerryne: Blue is sadness
Cara: Pink is happy

Us: Do you ever hear that red is associated with being hot?
Kerryne & Cara: no

Us:Do you ever head that blue is associated cold?
Kerryne & Cara: no

Alexa: anything that sounds like a fire alarm = bad
Kerryne & Cara agree.

Alexa: A lot of blind kids use computers. There's a program called ScreenReader

Us: What does a light wave look like?
Kerryne & Cara: a wave at the beach
Galia asked Kerryne to draw it.   She drew an oval-ish shaped spiral
Alexa: How did you know that waves curved?
Kerryne: when my hair is curled it's wavy.

Alexa suggested using a slinky to emulate a wave

Kerryne mentioned GoBall. It's a sport for blind people where a ball has bells in it and people roll the ball from one team member to the other.

Appendix K: Interviews at the Boston Museum of Science

April 25, 2007
Museum of Science Boston
Interview conducted by David Munger, Galia Traub, Mathew DeDonato

Met with Noreen Grice, who runs the planetarium and Maria Cabrera who is the head of museum outreach.

Noreen "Universal design doesn't get you far, so sometimes you have to use assistive technology, but when you combine the two, everyone is happy. Everyone needs to feel welcome; that is the key to a good exhibit."

Noreen and Maria took us into "mapping the world around us" exhibit, the museum's 1st truly universal exhibit. They pointed out several things to us
Consistency - Square audio button always to the left
General public doesn't read exhibits. Using "simple language and repetition" works well.
Tactile relief over an encased 3-d model
Staff is trained to assist blind guests. There are techniques and etiquette when working with the blind. Maria: "Put the person before the disability."

Noreen: With presentations in the planetarium, I try to use descriptive language.
Maria: in a given year I get ~300 VI guests that I know of. That number has gone up in recent years.

Then we went to the planetarium with Noreen
Us: How do you test your adaptations?
N: I try to buy something that has already been tested or run it by people I know who are blind.

How do you make tactile diagrams?
N: Zychrome swell machine. You print on the paper, bake it and then anything black pops up.

There are two types of Braille: grade 1 and grade2. Grade 1 is letter by letter. Grade 2 uses short hand for common words such as 'and', 'for'
Grade two is preferred, but for short labels grade on is fine (and more universal).

N: Captions go ABOVE picture

Why don't you use different textures to differentiate objects?
N: cost & harder to replicate.

Observations:
"smell boxes" Maria: you can buy liquid scents online
Bronze sculptures of animals to touch
Text over Braille makes it more accessible

Hot or cold exhibit: heated & cooled metal plates.
Weather Exhibit: walk thru tunnel

  At start: warm air, sounds of thunder, lightning (simulate warm air mass)

  At end: cool air, sounds or crickets (simulate cool air mass moving east)

Appendix L: Museum Experience Focus Group Protocol

Conducted with teachers of the visually impaired or their students. Should take 30-60min

>Introduce ourselves
>Explain our project

What museums have you been to?

What did you like about it? What did they do that made it easier for you to understand things?

What didn’t they like about it? Did they have exhibits that weren’t VI friendly?

What could they have done to make it better?

Appendix M: Museum Staff Adaptations Interview Protocol

Conducted with people who work at a museum and deal with making it accessible. This should take about an hour.

>Introduce ourselves
>Explain our project

How long have you been working at the museum?

How long have you been working to make exhibits accessible?

Could you show us some exhibits that are adapted for the visually impaired?

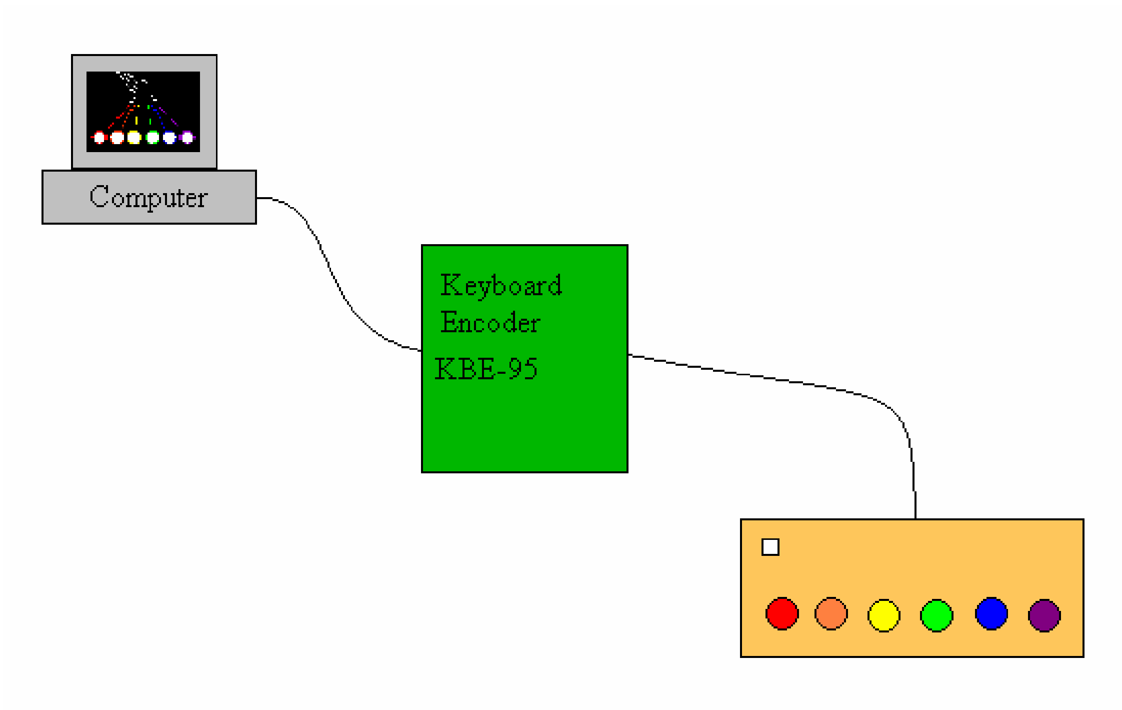
About how many VI visitors do you get each year?

Appendix N: Appropriate Language to use in the United Kingdom

According to Katie Gonzalez-Bell, former Accessibility Director for the Science Museum, the following language is appropriate to use in the United Kingdom.

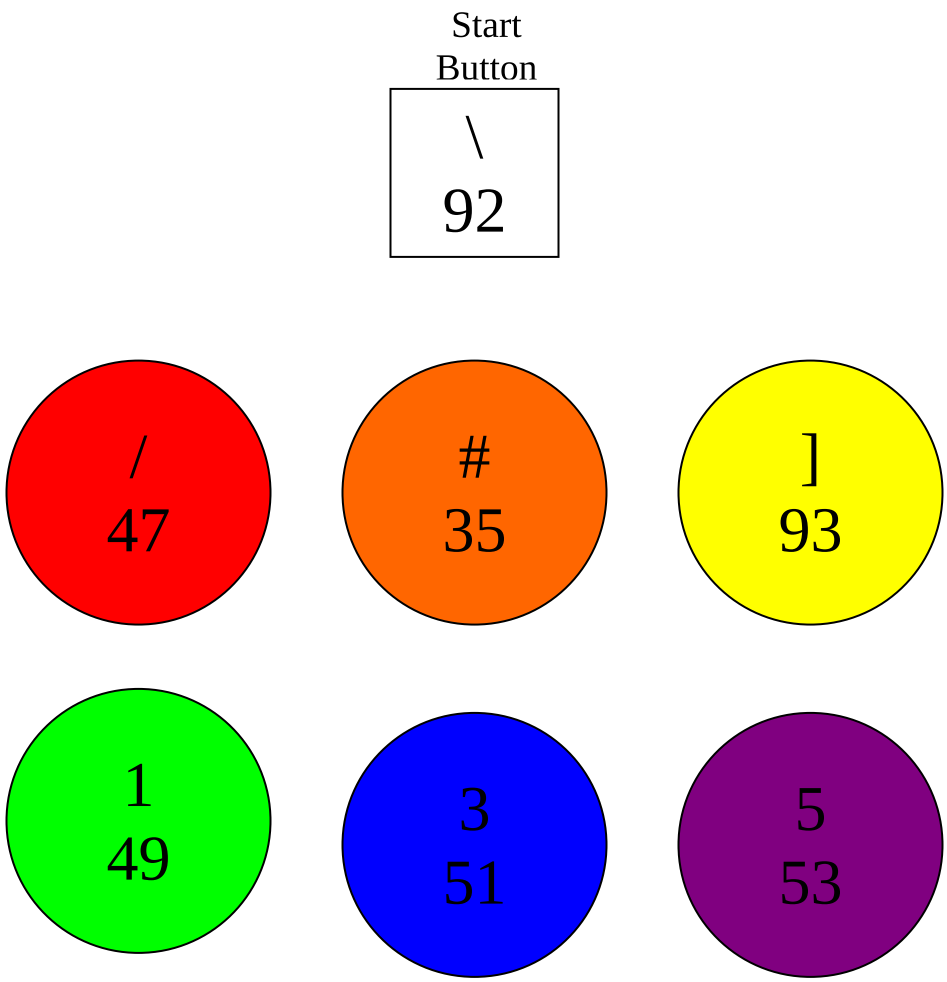
Do Not Use:	**Do Use:**
Cripple / Invalid / Handicapped	Disabled Person Person with a Disability
Victim of / Suffering from / Afflicted by	Person who has/with
Able-bodied / Normal	Non-disabled
Differing / Special needs	Requirements / Access needs / Needs
Mentally Handicapped / Retarded	Person with a learning difficulty / disability
Spastic / Epileptic	Person with Cerebral Palsy / Epilepsy
The disabled	Disabled people
Deaf and Dumb	Deaf without speech
Mongol / Down's Person	Person with Down's Syndrome
Wheelchair bound	Wheelchair user
The Deaf / The Blind	Deaf people / Hard of hearing people / People with visual impairments / Blind person
Disabled toilet	Accessible toilet
Mental	Person with mental health needs
Dwarf / Midget	Small person
Carer	Personal assistant

Appendix O: Visible Spectrum Prototype



This prototype is a combination of a flash animation along with a button box that connects to the computer. The button box is connected to the keyboard port of the computer using a keyboard encoder. For purposes of our model we used a keyboard encoder loamed to us by Ken Chan. A similar board can be used or can be purchased through Auden Electronics, we suggest model KEP-629. The buttons are then hooked up to the board so that the characters shown on the following page are produced.

Button Layout & Program Characters with ASCII values



Appendix P: Light Meter Parts List

B1 1.5 volt battery (C cell)

C1 0.1 uf capacitor (272-135)

PC1 Cadmium Sulfide photocell (276-1657)

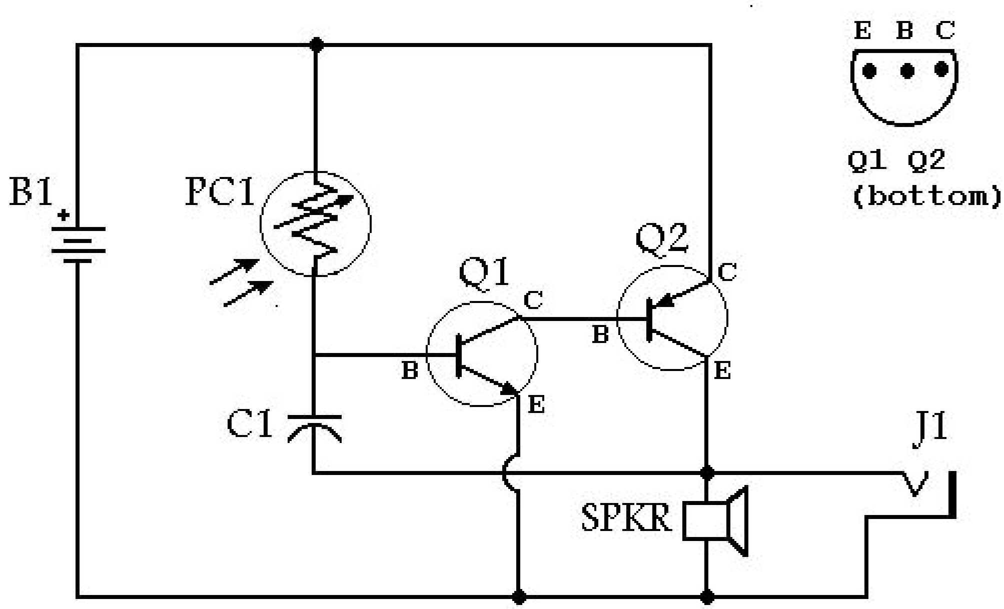
Q1 2N3904 NPN transistor (276-1603)

Q2 2N3906 PNP transistor (2N3906-ND)

SPKR 9-ohm miniature speaker (40-250 or similar)

J1 1/4" jack (274-280 or similar)

All part numbers are Radio Shack catalog



Appendix Q: Audio Prompt

Part 1

This exhibit explores the light spectrum.
All of the colors of the light spectrum combine to form white light.
The colors of the spectrum vary based on the wavelength of the light beam.
Each light here is represented by a different tone.

Part 2

Red corresponds to . . .

Part 3

Orange corresponds to . . .

Part 4

Yellow corresponds to . . .

Part 5

Green corresponds to . . .

Part 6

Blue corresponds to . . .

Part 7

And Purple corresponds to . . .

Part 8

White light is the combination of all colors.
So the representation of white light would sound like this . . .

<u>Part 9</u>
Colors can be combined to create different colors of the light waves.
Mixing light is not like mixing paint.
With paint, if you mix equal amounts of pure red, yellow and blue, you end up with black. Light can be mixed in a similar fashion. However, the difference is that light mixes towards white, rather than black. So therefore if you mix pure red, orange, yellow, green, blue, and purple, white is the final result.
The representation of magenta sounds like this…

<u>Part 10</u>
Now try finding the colors that mix to make magenta by pressing the buttons that correspond to those colors.

<u>Part 11</u>
Good job…Let's try another one…The representation of amber sounds like this…

<u>Part 12</u>
Now try finding the colors that mix to make amber, by pressing the buttons that correspond to those colors.

<u>Part 13</u>
Well done…Now you can try and combine the colors on your own by pressing the circular buttons in front of you.